Experiment No: 7 **Date:**

Title: power spectral density (PSD) of line codes

Objective: To write a MATLAB program to obtain and analyze the power spectral density of the following line codes:

1. Unipolar Signal
2. Polar Signal
3. Bipolar Signal
4. Manchester Signal

Theory:

In telecommunication, a line code (also called ***digital baseband modulation***, also called ***digital baseband transmission method***) is a code chosen for use within a communications system for baseband transmission purposes. Line coding is often used for digital data transport.

There are many reasons for using line coding. Each of the line codes offer one or more of the following advantages:

- Spectrum Shaping and Relocation without modulation or filtering. This is important in telephone line applications, for example, where the transfer characteristic has heavy attenuation below 300 Hz.
- Bit clock recovery can be simplified.
- DC component can be eliminated; this allows AC (capacitor or transformer) coupling between stages (as in telephone lines). Can control baseline wander (baseline wander shifts the position of the signal waveform relative to the detector threshold and leads to severe erosion of noise margin).
- Error detection capabilities.
- Bandwidth usage; the possibility of transmitting at a higher rate than other schemes over the same bandwidth.

At the very least the LINE-CODE ENCODER serves as an interface between the TTL level signals of the transmitter and those of the analog channel. Likewise, the LINE-CODE DECODER serves as an interface between the analog signals of the channel and the TTL level signals required by the digital receiver.

There are 2 major categories: ***return–to–zero (RZ)*** and ***nonreturn–to–zero (NRZ).*** With RZ coding, the waveform returns to a zero–volt level for a portion (usually one–half) of the bit interval.

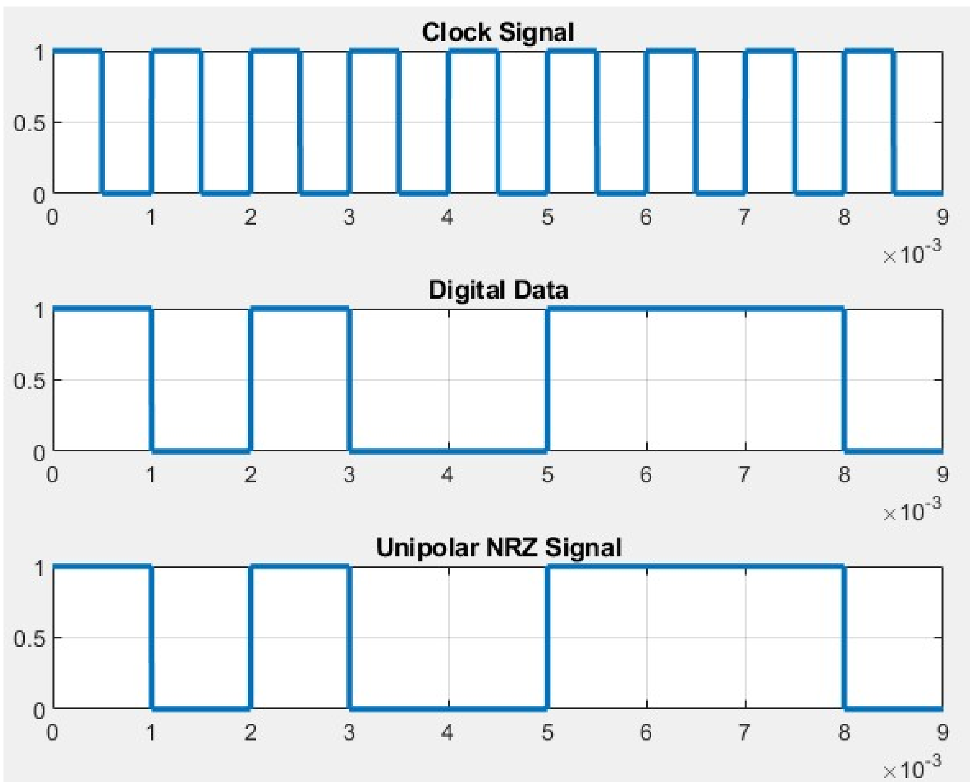
NRZ format is most widely used.

The waveforms for the line code may be further classified according to the rule that is used to assign voltage levels to represent the binary data.

1) Unipolar Signaling:

In positive–logic unipolar signaling, the binary 1 is represented by a high level (+A volts) and a binary 0 by a zero level. This type of signaling is also called ***on–off keying (OOK)***.

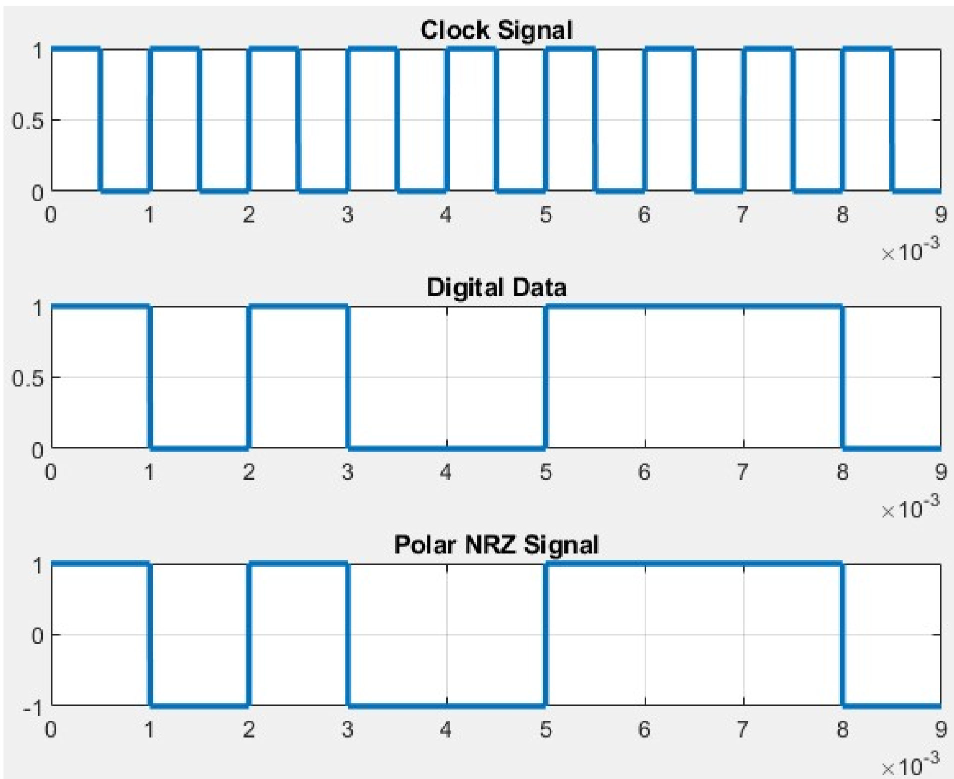
The time domain waveform of the same is as depicted in the following figure.



2) Polar Signaling:

Binary 1's and 0's are represented by equal positive and negative levels.

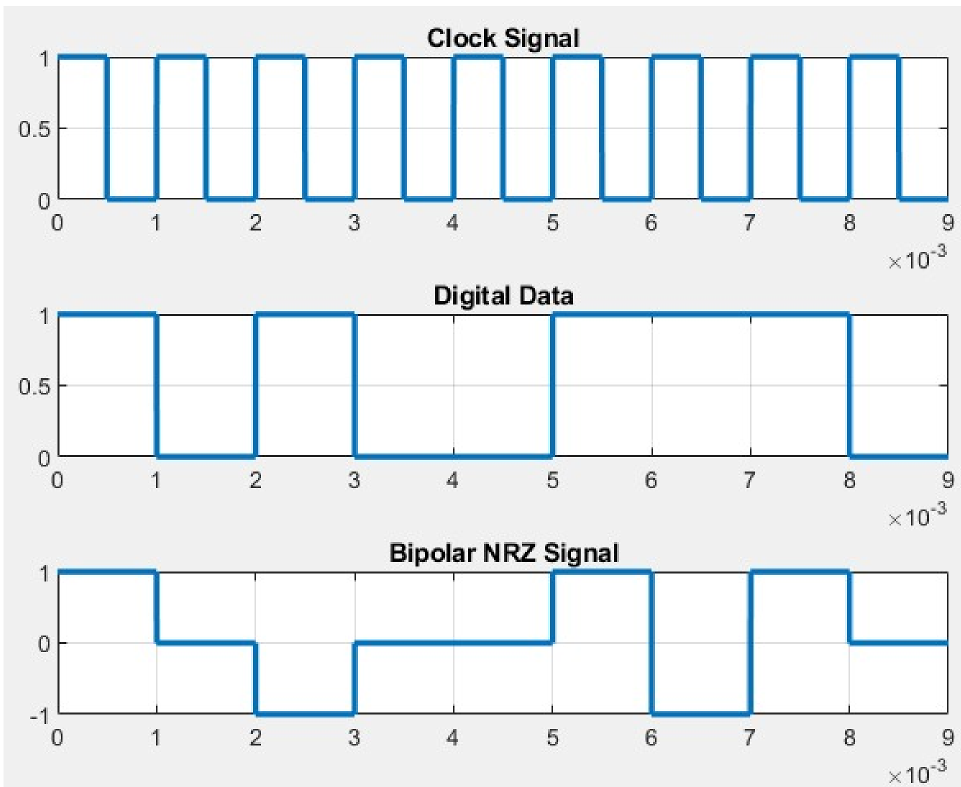
The time domain waveform of the same is as depicted in the following figure.



3) Bipolar (Pseudoternary) Signaling:

Binary 1's are represented by alternating positive or negative values. The binary 0 is represented by a zero level. The term pseudoternary refers to the use of 3 encoded signal levels to represent two–level (binary) data. This is also called ***alternate mark inversion (AMI)*** signaling.

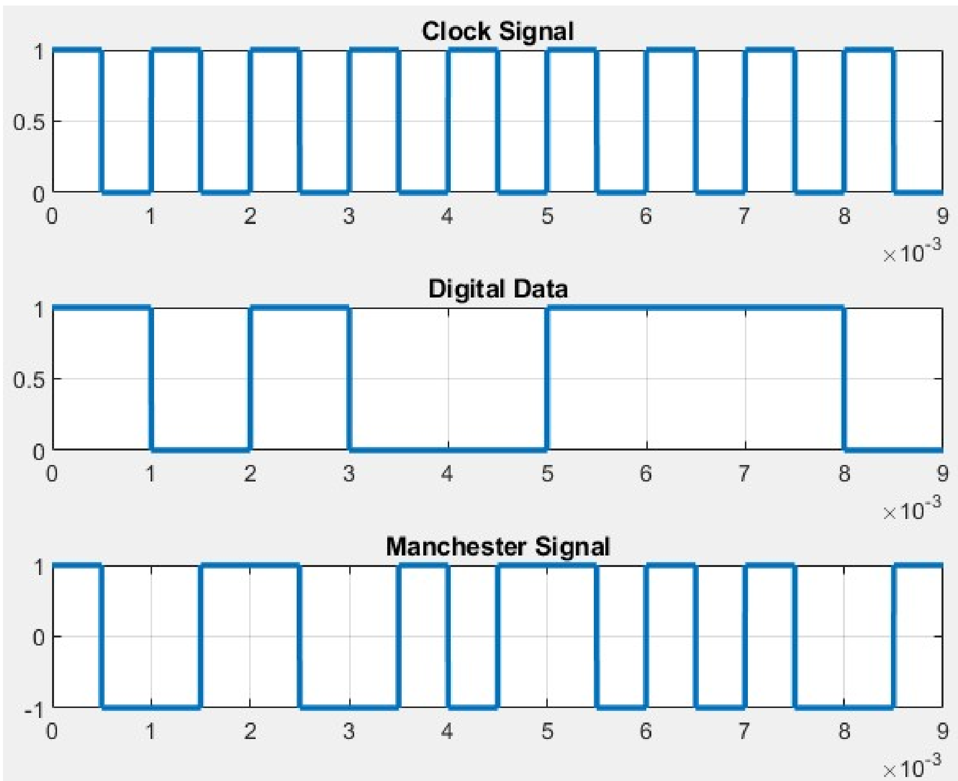
The time domain waveform of the same is as depicted in the following figure.



4) Manchester Signaling:

Each binary 1 is represented by a positive half–bit period pulse followed by a negative half–bit period pulse. Similarly, a binary 0 is represented by a negative half–bit period pulse followed by a positive half–bit period pulse. This type of signaling is also called ***split–phase encoding or bi-phase encoding***.

The time domain waveform of the same is as depicted in the following figure.



Power Spectral Density (PSD):

The power spectrum $S_{xx}(f)$ of a time series x(t) describes the distribution of power into frequency components composing that signal. The ***power spectral density (PSD)*** then refers to the spectral energy distribution that would be found per unit time, since the total energy of such a signal over all time would generally be infinite.

Then the power spectral density of $S_{xx}(f)$ of signal $x(t)$ is simply defined as the Fourier transform of autocorrelation sequence $R_{xx}(\tau)$:

$$S_{xx}(f) = FT\{R_{xx}(\tau)\}$$

$$S_{xx}(f) = \int_{-\infty}^{\infty} R_{xx}(\tau)\, e^{-j2\pi f\tau} d\tau$$

The autocorrelation sequence $R_{xx}(\tau)$ of signal $x(t)$ is given by:

$$R_{xx}(\tau) = \int_{-\infty}^{\infty} x(t+\tau)x^*(t)dt$$

Where $x^*(t)$ is the complex conjugation of the signal $x(t)$.

Similarly, in discrete time domain:

$$S_{xx}(\omega) = FT\{R_{xx}(n)\}$$

$$S_{xx}(\omega) = \sum_{n=-\infty}^{\infty} R_{xx}(n)e^{-j2\pi\omega n}$$

The autocorrelation sequence $R_{xx}(n)$ of signal $x(n)$ is given by:

$$R_{xx}(n) = \sum_{k=-\infty}^{\infty} x(n+k)x^*(k)$$

Sample calculation of autocorrelation sequence:

Let us take a right sided (i.e., the first sample is n=0) discrete time sequence $x(n) = \{1,2,3,4\}$

The sequence $x(n)$ is non zero in the interval $n = 0$ to $n = 3$ and its zero outside this interval. Since, there are N = 4 non zero samples, the autocorrelation will be having 2N-1 non zero samples.

1	2	3	4	0	0	0
0	0	0	1	2	3	4

0 + 0 + 0 + 4 + 0 + 0 + 0 = 4 = $R_{xx}(-3)$

1	2	3	4	0	0
0	0	1	2	3	4

0 + 0 + 3 + 8 + 0 + 0 = 11 = $R_{xx}(-2)$

1	2	3	4	0
0	1	2	3	4

0 + 2 + 6 + 12 +0 = 20 = $R_{xx}(-1)$

1	2	3	4
1	2	3	4

1 + 4 + 9 + 16 = 30 = $R_{xx}(0)$

0	1	2	3	4
1	2	3	4	0

0 + 2 + 6 + 12 +0 = 20 = $R_{xx}(1)$

0	0	1	2	3	4
1	2	3	4	0	0

0 + 0 + 3 + 8 + 0 + 0 = 11 = $R_{xx}(2)$

1	2	3	4	0	0	0
0	0	0	1	2	3	4

0 + 0 + 0 + 4 + 0 + 0 + 0 = 4 = $R_{xx}(3)$

$R_{xx}(n)$ is ***real*** and ***symmetric*** about origin ***in time domain***.

∴ PSD $S_{xx}(\omega) = FT\{R_{xx}(n)\}$ is ***pure real*** function of ***frequency ω.***

The power spectral densities of line codes can be found by similar means i.e., by taking the Fourier transform of the line codes' autocorrelation sequence.

PSD of Unipolar NRZ:

$$S_{xx}(f) = \frac{a^2}{4} T_b sinc^2(fT_b) + \frac{a^2}{4}\delta(f) + 0.5T_b sinc^2(fT_b) + 0.5\delta(f)$$

PSD of Polar NRZ:

$$S_{xx}(f) = a^2 T_b sinc^2(fT_b)$$

PSD of Bipolar NRZ:

$$S_{xx}(f) = a^2 T_b sinc^2(fT_b) sin^2(\pi f T_b)$$

PSD of Manchester code:

$$S_{xx}(f) = a^2 T_b sinc^2\left(f\frac{T_b}{2}\right) sin^2\left(\frac{\pi f T_b}{2}\right)$$

Where, a is amplitude level, $T_b$is the bit duration and the delta function is Dirac delta (continuous time impulse function).

Algorithm:

1. Define the input parameters: bit rate, bit duration and frequency
2. Calculate the power spectral density for Unipolar Signal, Polar Signal, Bipolar Signal and Manchester Signal
3. Plot the power spectral density for all the four signals

MATLAB Script:

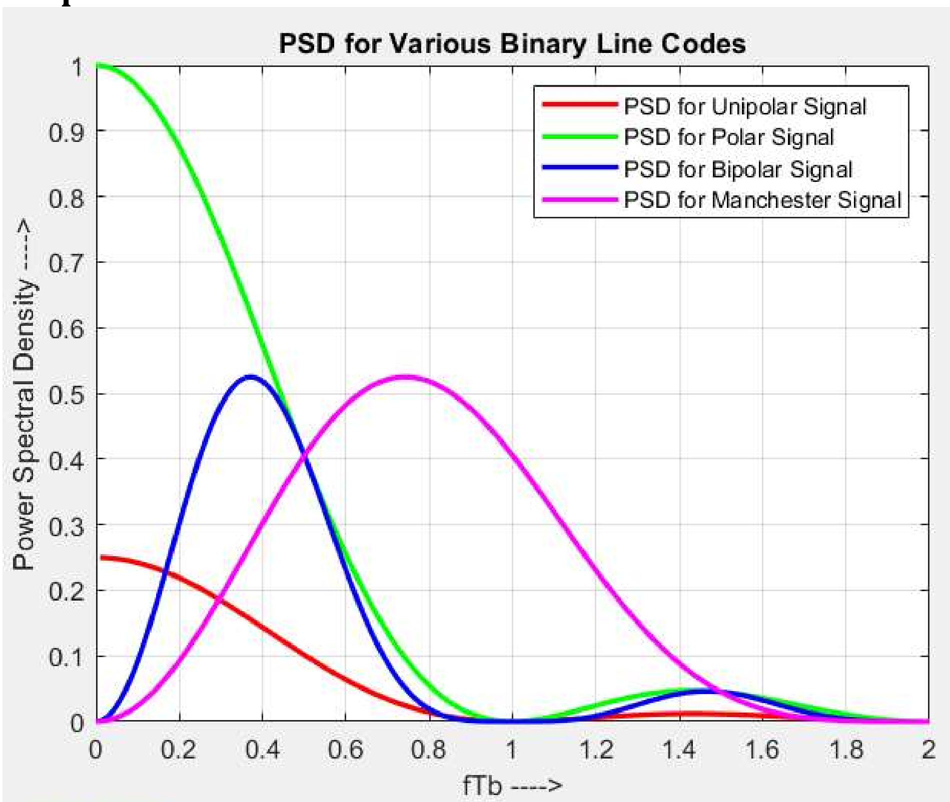
```
clear all;
close all;
clc;

%Input Parameters
Rb=1;% Bit rate in bits per second
Tb=1/Rb; % Bit duration
f=0:0.01*Rb:2*Rb; % frequency from 0 to 2 times the bit rate
x=f*Tb;
% Power Spectral Density of Unipolar Signal
%-----------------------------------------------------------------
-----------
P1=0.25*Tb*(sinc(x).*sinc(x))+ 0.25 *dirac(f);
%-----------------------------------------------------------------
-----------
% Power Spectral Density of Polar Signal
```

```
%-----------------------------------------------------------------
-----------
P2=Tb*(sinc(x).*sinc(x));
%-----------------------------------------------------------------
-----------
% Power Spectral Density of Bipolar Signal
%-----------------------------------------------------------------
-----------
P3=Tb*(sinc(x)).^2.*(sin(pi*x)).^2;
%-----------------------------------------------------------------
-----------
% Power Spectral Density of Manchester Signal
%-----------------------------------------------------------------
-----------
P4=Tb*(sinc(x/2)).^2.*(sin(pi*x/2)).^2;
%-----------------------------------------------------------------
-----------
% Plotting Power Spectral Density of Binary line codes
%-----------------------------------------------------------------
-----------
figure(1),
plot(f,P1,'r'),hold on
plot(f,P2,'g')
plot(f,P3,'b')
plot(f,P4,'m')

grid on
box on
xlabel('fTb ---->')
ylabel('Power Spectral Density ---->')
title('PSD for Various Binary Line Codes')
legend('PSD for Unipolar Signal','PSD for Polar Signal',...
    'PSD for Bipolar Signal','PSD for Manchester Signal')
```

Output:


PSD for Various Binary Line Codes
PSD for Unipolar Signal
PSD for Polar Signal
PSD for Bipolar Signal
PSD for Manchester Signal
Power Spectral Density ---->
fTb ---->
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Inference:

Space for MATLAB Script (Open Ended):

Students are instructed to write the MATLAB script for time domain waveforms of:

1. **Unipolar NRZ Signal**
2. **Polar NRZ Signal**
3. **Bipolar NRZ Signal**
4. **Manchester NRZ Signal**

Also attach the screenshot of the output.

Evaluation:

Attendance (2)	
Journal (3)	
Conduction (5)	
Viva (5)	
Total (15)	
Signature of faculty-in-charge with date	